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Experimental Investigation of Performance and Emission Characteristics of Simarouba Biodiesel and Its Blends on LHR Engine

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Abstract: *Diesel is a fossil fuel that is getting depleted at a fast rate. So an alternative fuel is necessary and a need of the hour. simarouba oil, which is cultivated in India at large scales, has a high potential to become an alternative fuel to replace diesel fuel. Direct use of simarouba oil cannot be done, as its viscosity is more than the diesel fuel, and hence affects the combustion characteristics. The simarouba oil is esterified to reduce the viscosity and it is blended with diesel on volume basis in different proportions. The use of thermal barrier coatings (TBCs) to increase the combustion temperature in diesel engines has been pursued for over 20 years. Increased combustion temperature can increase the efficiency of the engine, decrease. However, TBCs have not yet met with wide success in diesel engine applications because of various problems associated with the thermo-mechanical properties of the coating materials. Although, the in-cylinder temperatures that can be achieved by the application of ceramic coatings can be as high as 850-9000C compared to current temperatures of 650-7000C. The increase in the in-cylinder temperatures helped in better release of energy in the case of biodiesel fuels thereby reducing emissions at, almost the same performance as the diesel fuel. Here the effort has been made to determine the performance and emission characteristics of SOME blend with diesel in conventional engine and LHR engine.*

Keywords: *LHR Engine, normal engine Biodiesel, Simarouba oil, SOME, Performance and Emission Characteristics, Thermal barrier coating.*

I. Introduction

Petroleum based fuels play a vital role in rapid depletion of conventional energy sources along with increasing demand and also major contributors of air pollutants. Major portion of today's energy demand in India is being met with fossil fuels. Hence it is high time that alternate fuels for engines should be derived from indigenous sources. As India is an agricultural country, there is a wide scope for the production of vegetable oils (both edible and non-edible) from different oil seeds. The present work focused only on non-edible oils as fuel for engines, as the edible oils are in great demand and far too expensive. The past work revealed that uses of vegetable oils for engines in place of diesel were investigated. Though the concerned researchers recommended the use of vegetable oils in diesel engines, there was no evidence of any practical vegetable oil source engines.

It is known that the efficiency of internal combustion diesel engines changes 38-42%. It is about 60% of the fuel energy dismissed from combustion chamber. To save energy, combustion chamber component are coated with low thermal conduction materials. The effect of thermal barrier coating on the cylinder components like piston crown top, cylinder liner, cylinder head inside and valves. The thermal barrier coated engines are otherwise known as low heat rejection (LHR) engines. Due to the insulation of the cylinder wall the heat transfer through the cylinder walls to the cooling system is reduced which change the combustion characteristics of the diesel engine. To know the changes during combustion the steady-state LHR engines operation have been studied by applying either the first or second law of thermodynamics. The state of the art of the thermal barrier coating is the yattria stabilized zirconia. In addition, other material systems have been investigated for the next generation of TBC. The study also focuses on coating method for Yattria Stabilized Zirconia (YSZ) to improve coating under high load and temperature cyclical conditions encountered in the real engine. The effect of insulation on engine performance, heat transfer characteristics, combustion and emission characteristics are studied and compared with standard (STD) diesel engine

II. Materials and Methods

The extraction of biodiesel is carried out by base catalyzed transesterification method.

2.1. Process of Extracting

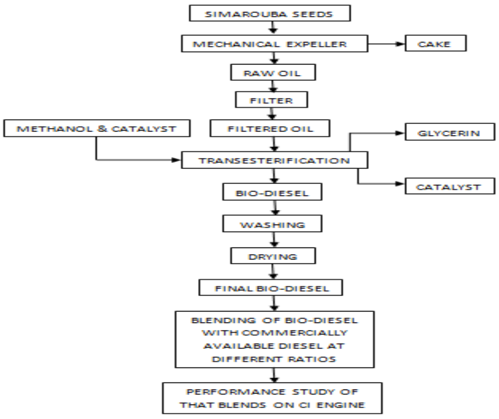

Fig 2.1: The flow chart for biodiesel production

To a one liter of raw Simaroauba oil is heated up to 70^0C. 300 ml of methanol & 5-7gms of NaOH (catalyst) is added and the mixture is maintained at 65-70^0C is about 1½ hours and stirred continuously. The mixture is allowed to settle for 20-30 min until the formation of biodiesel and glycerin layers. The glycerin is removed from the bio-diesel in a separating funnel. The bio diesel produced from Simarouba oil is ready to use.

2.2. Transesterification

It is most commonly used and important method to reduce the viscosity of vegetable oils. In this process triglyceride reacts with three molecules of alcohol in the presence of a catalyst producing a mixture of fatty acids, alkyl ester and glycerol. The process of removal of all the glycerol and the fatty acids from the vegetable oil in the presence of a catalyst is called esterification.

CH2COOR1 | CHCOOR2 | CH2COOR3 + 3ROH ⟷ Catalyst (NaOH) CH2OH | CHOH | CH2OH + R1COOR | R1COOR | R1COOR

Cottonseed Glyceride Alcohol Glycerin Biodiesel

Chemical reaction

Physical and chemical properties are more improved in esterified vegetable oil because esterified vegetable oil contains more cetane number than diesel fuel. These parameters induce good combustion characteristics in vegetable oil esters. So unburnt hydrocarbon level is decreased in the exhaust. It results in lower generation of hydrocarbon and carbon monoxide in the exhaust than diesel fuel. The vegetable oil esters contain more oxygen and lower calorific value than diesel. So, it enhances the combustion process and generates lower nitric oxide formation in the exhaust than diesel fuel.

III. Properties of Diesel and Some Blends

After transesterification the properties of Simarouba oil blends was determined. It was found that the properties of Simarouba oil blends were similar to diesel. Simarouba oil blends were similar to diesel.

Table 3.1: Properties of Simarouba oil blends

Properties	Diesel	S20	S40	S100
Kinematic viscosity at 40_0C (Cst)	2.54	3.104	3.891	5.6
Calorific value (kJ/Kg)	42500	42270	41949	37933
Density (kg/m_3)	840	838	846	875
Flash Point (^{0}C)	54	79	98	165
Fire Point (^{0}C)	64	89	110	185

IV. Experimental Setup

The experimental setup enables study performance, combustion and emission characteristics. The experiments have been carried out on a DI compression ignition engine for various blends of simarouba oil with diesel (S20, S40, S60, S80, and S100) with varying brake power. The experiment is carried out at constant compression ratio of 17.5:1 and constant injection pressure of 200 bar by varying brake power.

Fig 4.1: Photograph of engine setup

Table 4.1: Engine specifications

Manufacturer	Kirloskar oil engines Ltd, India
Model	TV-SR, naturally aspirated
Engine	Single cylinder, DI
Bore/stroke	87.5mm/110mm
Compression Ratio	17.5:1
speed	1500r/min, constant
Rated power	5.2kw
Working cycle	4 stroke
Injection pressure	200bar/23 def TDC
Type of sensor	Piezo electric
Response time	4 micro seconds

V. Result and Discussion

After detail study of performance and emission characteristics of simarouba biodiesel and its blends in normal engine and low heat rejection engine it can be seen that 20% simarouba biodiesel blend and diesel are having same almost same characteristics so here the comparative analysis is carried out between normal engine and LHR engine.

5.1 Performance characteristics

5.1.1 Specific fuel consumption

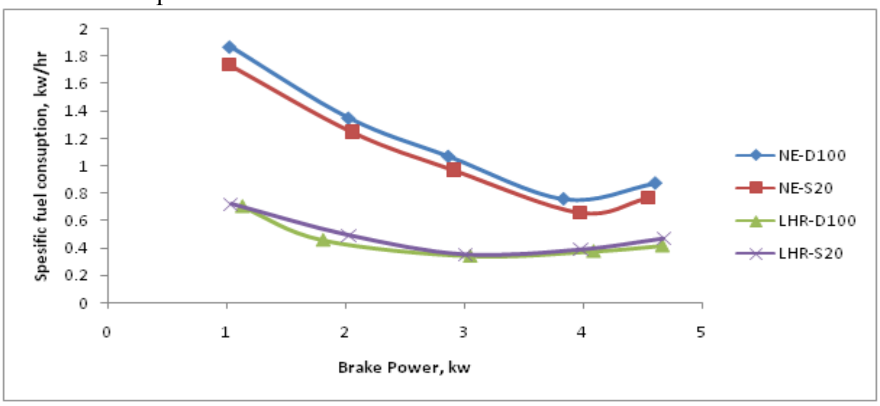

Fig 5.1 The variation of the specific fuel consumption with brake power for diesel and simarouba blends

Fig 5.1 shows the specific fuel consumption for simarouba biodiesel and its blends with respect to brake power for both normal engine and LHR engine. At maximum load the specific fuel consumption of LHR engine fuelled with biodiesel is higher than LHR engine fuelled with diesel and lower than normal engine fuelled with diesel and biodiesel. This higher fuel consumption was due to the combined effect of lower calorific value and high density of biodiesel. The test engine consumed additional biodiesel fuel in order to retain the same power output. Because the reason is heat leakage in engine cylinder is developed therefore the amount of fuel required to generate 1kw of power compare to without LHR.

5.1.2 Air fuel ratio

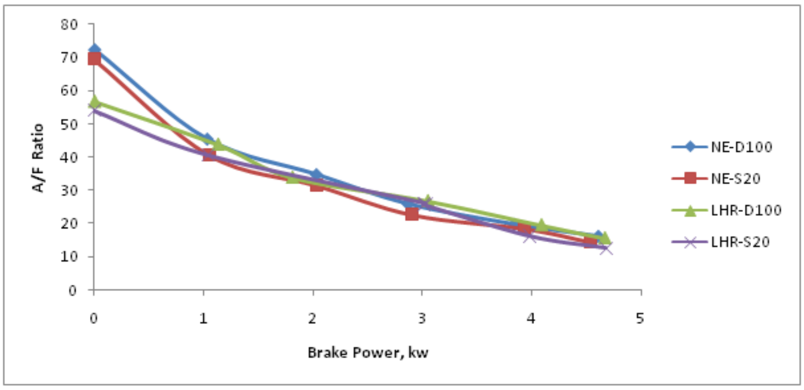

Fig 5.2 The variation of the air fuel ratio with brake power for diesel and simarouba blends

The variation of air fuel ratio for diesel and 20% SOME blend is shown in fig 5. 2 for both normal engine and LHR engine. Fuel consumption is higher in case of LHR engine due to increased temperature and completes combustion. Air fuel ratio decreases with increase in load because air fuel mixing process is affected by the difficulty in atomization of biodiesel due to its higher viscosity.

5.1.3 Brake thermal efficiency

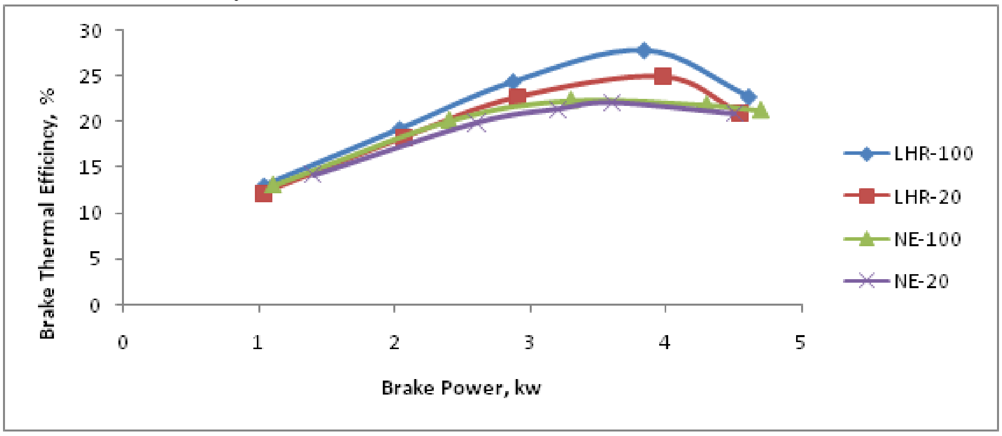

Fig 5.3 The variation of the brake thermal efficiency with brake power for diesel and simarouba blends

The variation of the brake thermal efficiency with load for diesel and SOME blends are shown in figure 5.3. We can observe that S20 with LHR has higher brake thermal efficiency than normal engine D100 this is because of increased combustion rate which provides complete burning of fuel and due to low heat rejection. The thermal efficiency of S20 is lower than diesel because the reason is large difference in viscosity, specific gravity and volatility.

5.1.4 Exhaust gas emission

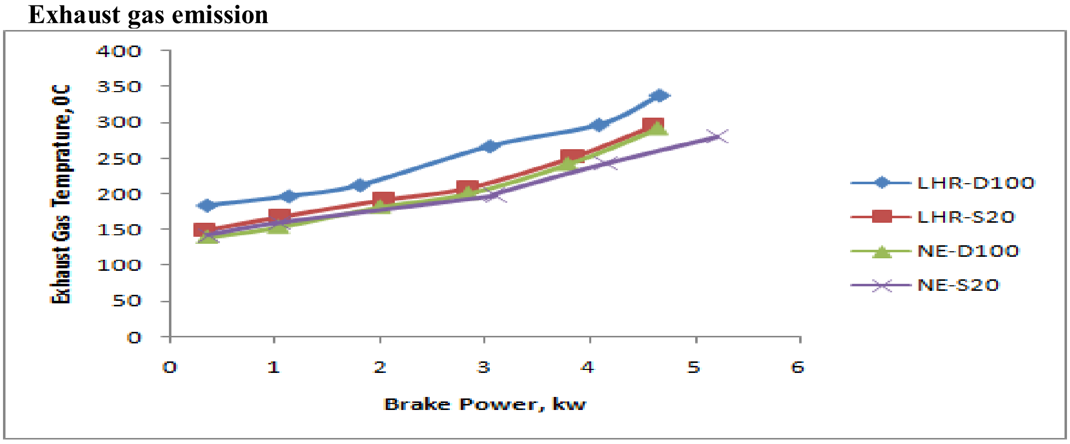

Fig 5.4 The variation of the exhaust gas temperature with brake power for diesel and simarouba blends

The variation of the exhaust gas temperature with load for diesel and SOME blends are shown in figure 5.4. When bio fuel concentration increases the exhaust temperature increase. The same also when load increases the exhaust temperature increases. Because the reason is the heat release rate by the biodiesel during the expansion is comparatively lower than diesel.

5.2 Emission characteristics

5.2.1 Carbon monoxide

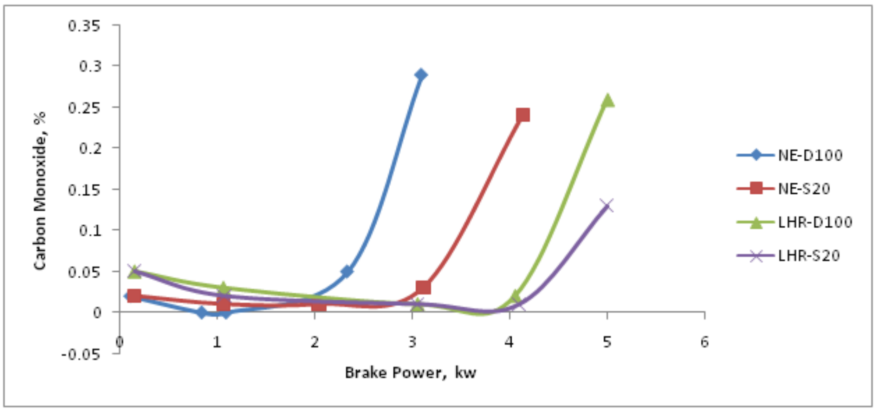

Fig 5.5 The variation of the carbon monoxide with brake power for diesel and simarouba blends

The variation of carbon monoxide (CO) with engine power output is presented in figure 5.5. The fuels are producing higher amount of carbon monoxide emission at low power outputs and giving lower values at higher power conditions. Carbon monoxide emission decreases with increasing power output. With increasing biodiesel the 20% CO emission level decreases. Biodiesel itself has about 11 % oxygen content in it and it may helps for the complete combustion. Hence, CO emission level decreases with increasing biodiesel percentage in the fuel.

5.2.2 Hydro carbon

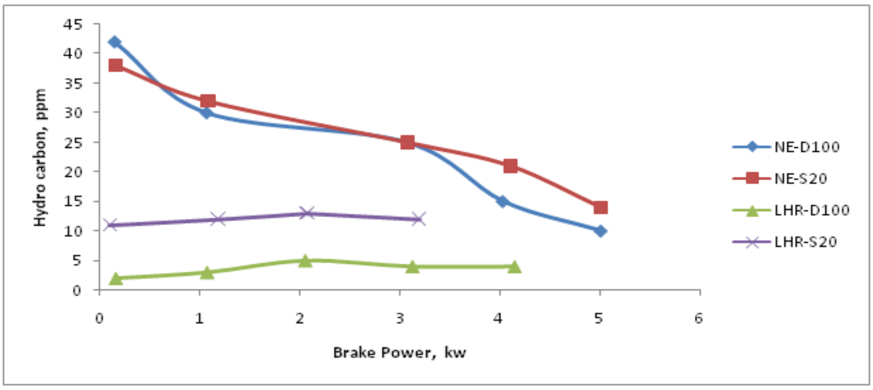

Fig 5.6 The variation of the hydro carbon with brake power for diesel and semarouba blends

The variation of hydrocarbon (HC) with respect to engine power output for different fuels are shown in figure 5.6. The high operating temperature in LHR engine makes the combustion nearly complete than the limited operating temperature condition as in the case of diesel engine. All full load hydrocarbon emission levels are decreases for LHR engine fueled with biodiesel than LHR engine fueled with diesel and diesel engine fueled with diesel. The air fuel mixture, which was accumulated in the crevice volume, was reduced due to the high temperature and availability of oxygen, which in turn leads to reduction in unburned hydrocarbon emissions.

5.2.3 Nitrogen oxide

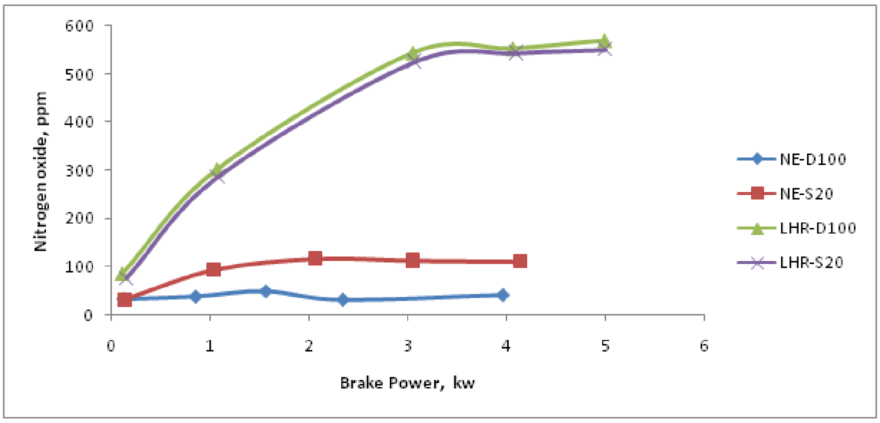

Fig 5.7 The variation of the nitrogen oxide with brake power for diesel and semarouba blends

Figure 5.7 shows the variation of oxides of nitrogen with engine power output. The main reason for the formation of oxides of nitrogen in an IC engines are high temperature and availability of oxygen. At maximum load, NOx emission for LHR engine with biodiesel fuel is higher. In LHR engine, the operating conditions are in favor of NO species and such as the availability of oxygen in the fuel itself other than the oxygen available in the air and high temperature due to insulation coating, which enhance the NO species formation.

VI. Conclusion

- As detail study of performance characteristics of simarouba biodiesel and its blends on normal engine we can observe that 20% blend of simarouba biodiesel in diesel fuel has almost same mechanical efficiency, same specific fuel consumption.
- We can also see that there is slight increase in brake thermal efficiency which is a positive sign with this blend.. So we can conclude that without any modification in engine we can save diesel fuel for certain extent without any compromise with standard performance characteristics and in future semarouba biodiesel can be a best alternative fuel which can replace the diesel.
- As same parameters studied with engine modification, here we observed that there is increase in performance parameters than normal engine. There is increase in parameters like brake thermal efficiency, mechanical efficiency and there is decrease in specific fuel consumption and fuel consumption which can be observed in comparative graph.
- By studying performance characteristics on normal engine and low heat rejection engine, it can concluded that with 20% blend we can achieve same characteristics as that of diesel fuel so S20 is the best blend and in future simarouba methyl ester can be a best and most suitable alternative fuel which can replace diesel fuel for years to come and with thermal barrier coating we can meet needy requirements.
- Simarouba biodiesel shows lower heat release rate during premixed burning phase compared to diesel. The high viscosity and poor volatility of NE-D100 result in poor atomization and fuel air mixing rates. Heat release rate is more in LHR-S20 compared to LHR-D100 and heat release rate in NE-D100 and NE-S20 are almost similar.
- We can conclude that the S20 with LHR shows same graphs as compared to D100 this blend is best suitable for an engine.
- It was found that, CO and HC emissions for LHR engine with biodiesel was considerably lower than LHR engine fueled with diesel. This reduction of emissions due to excess oxygen availability along with higher operating temperature.
- NO emission for LHR engine with biodiesel fuel was higher than LHR engine fueled with diesel. The operating conditions of LHR engine were favorable to NO formation. However this increase in emission level was within the acceptable limits.

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